RIVER DIVERSION WORKS

1. General

Most of the hydraulic structures are constructed in the area with flowing water. Therefore, the main flow has to be diverted away from the construction site in order to facilitate the construction of main structures e.g. dams, powerhouse, bridge piers, navigation locks. River Diversion Works include set of structures, which are required to handle a river during construction of such main structures.

2. Components of a diversion scheme

The components of a diversion scheme generally include a cofferdam for the diversion of flow, conveyance canal or tunnel/s and dewatering and drainage of construction areas.

2.1 Cofferdams

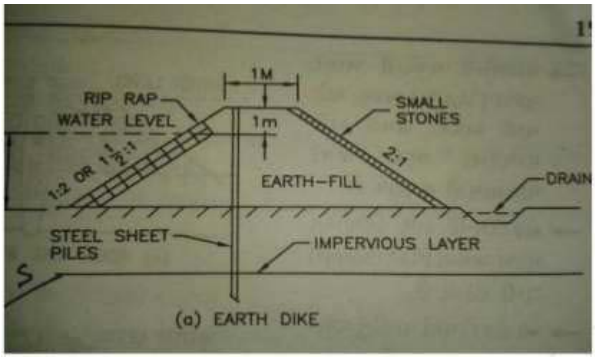
Cofferdams are generally temporary structures used to divert water from an area where permanent structure has to be constructed. In some cases diversion cofferdams are constructed in order to construct main cofferdam. These structures often involve a large quantity of construction material; therefore, they might be used as a part of permanent structures.

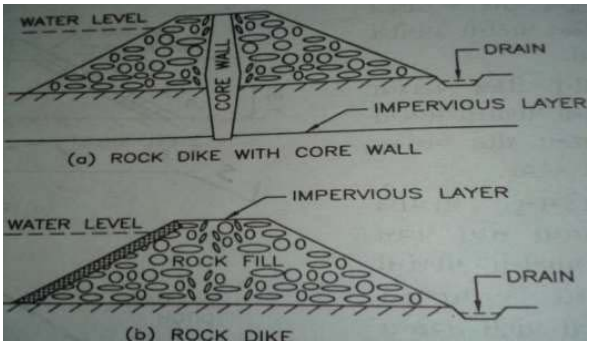
RIVER DIVERSION WORKS

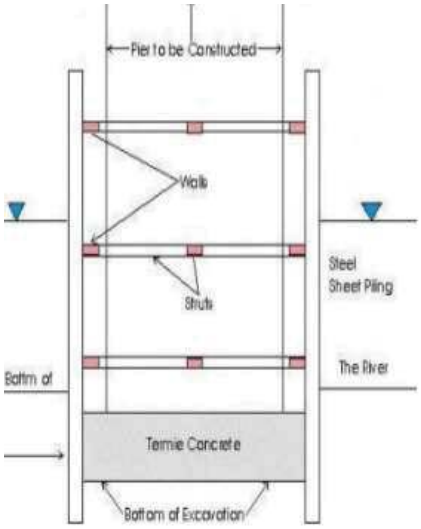
The cofferdams can be constructed using various materials, but the common types being the followings:

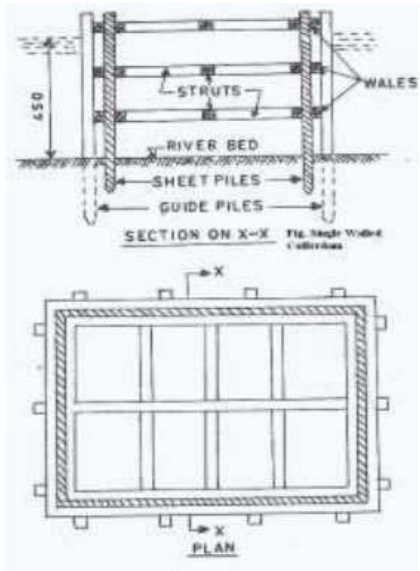
- Embankments: earth, earth-rockfill, sand
- Concrete: conventional, roller-compacted
- Metallic: sheet piles, cells

Earth and rockfill cofferdams are the most commonly used structures for diversion and protection of the work area during the construction of the main structures. However, due to the layout difficulties and other constraints, concrete or cellular cofferdams may be of better choice than embankment cofferdams. For instance, the base width and length of the cellular cofferdam perimeter are significantly shorter than that of an embankment cofferdam which often form basis of the choice between two alternatives in narrow reaches. Similarly, for the sheet pile type, the quantity of fill is less than one-half per unit of length for cofferdams of equal height.

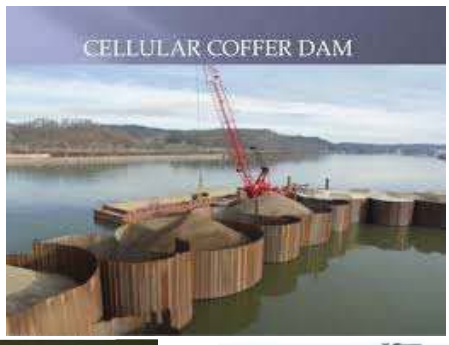

1M
RIP RAP
WATER LEVEL
1m
SMALL STONES
2:1
1:2 OR 1½:1
EARTH–FILL
DRAIN
STEEL SHEET PILES
IMPERVIOUS LAYER
(a) EARTH DIKE

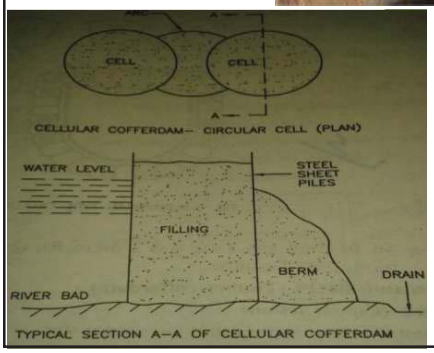

WATER LEVEL
CORE WALL
DRAIN
IMPERVIOUS LAYER
(a) ROCK DIKE WITH CORE WALL
IMPERVIOUS LAYER
WATER LEVEL
ROCK FILL
DRAIN
(b) ROCK DIKE

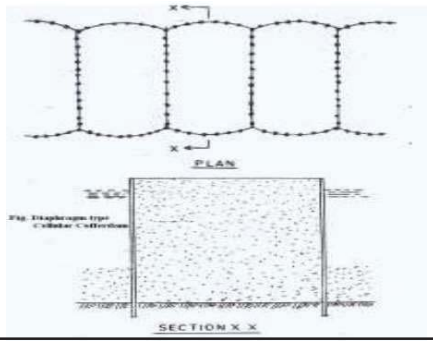

Pier to be Constructed
Walls
Struts
Steel Sheet Piling
The River
Bottm of
Termie Concrete
Bottom of Excavation


STRUTS
WALES
450
RIVER BED
SHEET PILES
GUIDE PILES
SECTION ON X–X
X
X
PLAN

RIVER DIVERSION WORKS







RIVER DIVERSION WORKS

2.2 Conveyance system

The second component of the diversion works is conveyance system, through which the diverted flow is conveyed to the river downstream of cofferdam. The flow can be conveyed through different conveyance system as mentioned below:

- channels (free surface); natural, artificial, lined, unlined, controlled, uncontrolled flow
- conduits (free surface flow, pressure flow)
  - metallic pipes
  - concrete conduits
  - tunnels - lined, unlined, controlled, uncontrolled flow

RIVER DIVERSION WORKS

2.3 Dewatering and drainage of construction site

Usually, the high ground water table and seepage water passing through the cofferdam make the construction of main structure difficult. Therefore, dewatering and drainage of construction zone is done in order to facilitate the construction of main structure. The works mainly involve the followings:

- Trench/ channel construction
- Pumping
- Drainage, filter construction

3.0 Importance of diversion schemes

River diversion works constitute one of the important components of water resources projects as the construction of main structures, especially large hydraulic structures is not possible without implementation of a good diversion scheme. The costs of the diversion scheme are high, often represent 5-10% of total cost when large discharges have to be handled. For the construction of cofferdam of Tukrui HEP, Brazil, about 12 million cubic meter of embankment material were placed.

4. Basic Planning Considerations

4.1 Phases of river diversion

In many cases the construction of a dam will require more than one phase of handling the river flows. The complete sequence of phases is important. As far as possible, the efforts should be made to integrate with permanent structures while planning river diversion work. For instance, if the construction works are planned in two or more phases, part of the structure completed in the first phase may be used as a diversion facility (spillway or sluice) during the second phase of construction. Refer Fig .1 (Linsley and Franzini, 1979) and Fig 2.

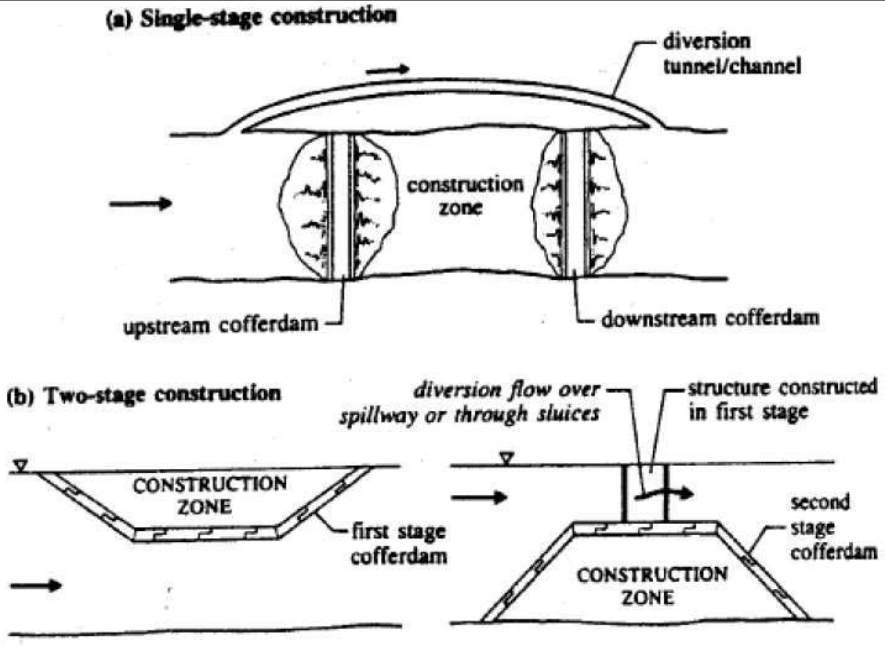


Fig 1:Stream flow diversion by cofferdams

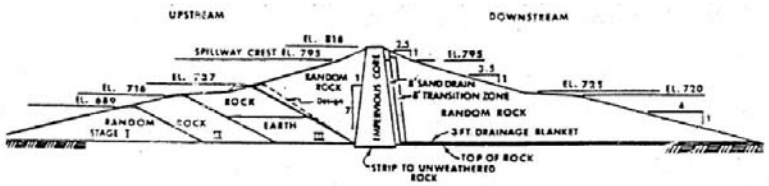


Fig 2.a: Three-stage cofferdam of East Fork Dam

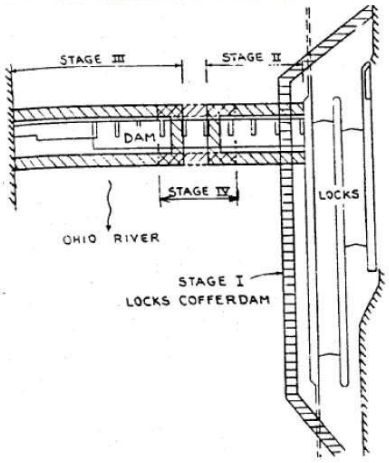


Fig 2.b: Four-stage cofferdam of Pike Island Locks and Dam

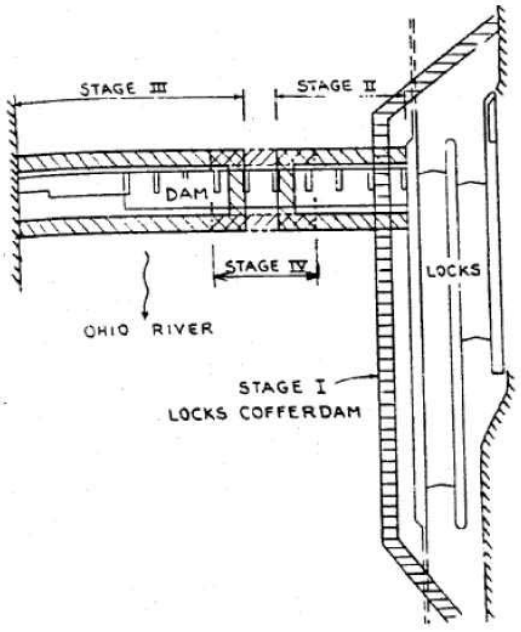


Fig 2.b: Four-stage cofferdam of Pike Island Locks and Dam

4.2 Relationship between river diversion scheme and layout of permanent structures

Well relationship between river diversion scheme and layout of permanent structures should be maintained considering:

- Available space
- Hydraulic conditions, geological conditions
- Possibility to incorporate temporary structures in permanent structures
- Feasibility of construction of diversion structure.

4.3 Relationship between river diversion and hydrological cycle of the river

Components of river diversion schemes often have to be constructed in the riverbed, with flowing water. To obtain more favorable (or feasible) conditions, dry period (low discharges) is generally chosen. For Himalayan rivers which have significant snowmelt contribution, the drier months are usually February and March, whereas for non-Himalayan rivers April , May are more favorable for the river closure works.

4.4 Capacity of diversion works

The capacity of a diversion work is based on hydrological safety. In general, the larger the design floods, the higher the cost of diversion works. The selection of discharge capacity of the diversion structures is fundamental for:

- Definition of cofferdam height (stage - discharge relationship)
- Definition of size of conveyance system such as diversion tunnel diameter, channel width and depth concept of submersible cofferdams

The selection of the design flood for the diversion works depends on the risk, that one is prepared to take. For example, a more conservative design flood has to be considered for situation where overtopping during construction would have disastrous results. Therefore, the discharge capacity is to be decided on the basis of a risk analysis.

Example:

Let T_r - return period of a flood for which no damage or destruction should occur

C - total cost of diversion scheme having required capacity (corresponding to T_r)

D - estimation of damages resulting from a failure of the diversion scheme (for instance overtopping and destruction of a cofferdam). Includes damages downstream and at site.

R - risk of occurrence of a flood larger than diversion capacity during diversion period (N years)

$$R = 1 - (1 - 1/T_r)^N$$

E = R * D

R - Risk of occurrence

D - Total Damage

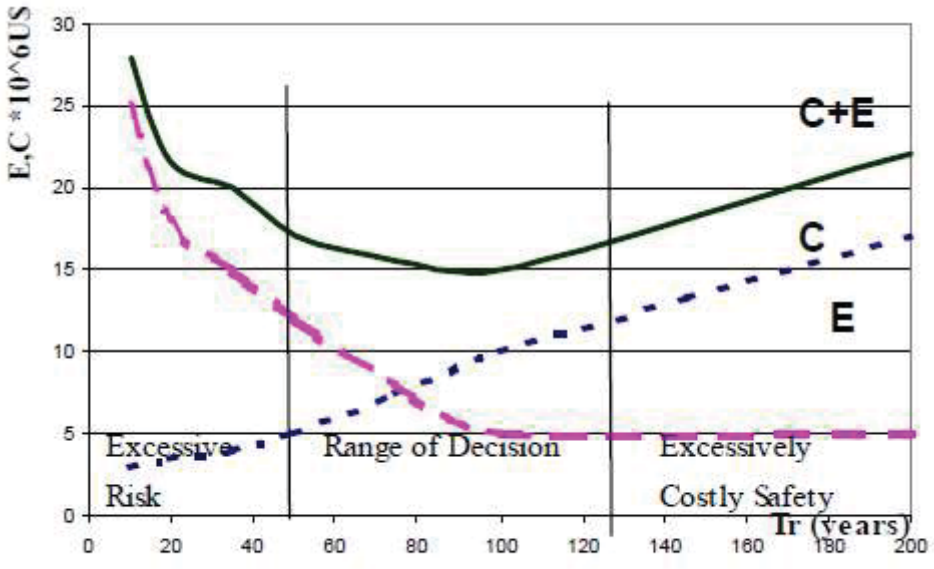


Fig 3: Optimum cost of a diversion work

Theoretically speaking, the design flood / a period of return is selected, which corresponds to a minimum combined cost, C+E of diversion works as well as total damage expected due to overtopping /failure of diversion works.

5. Special Considerations of River Diversion

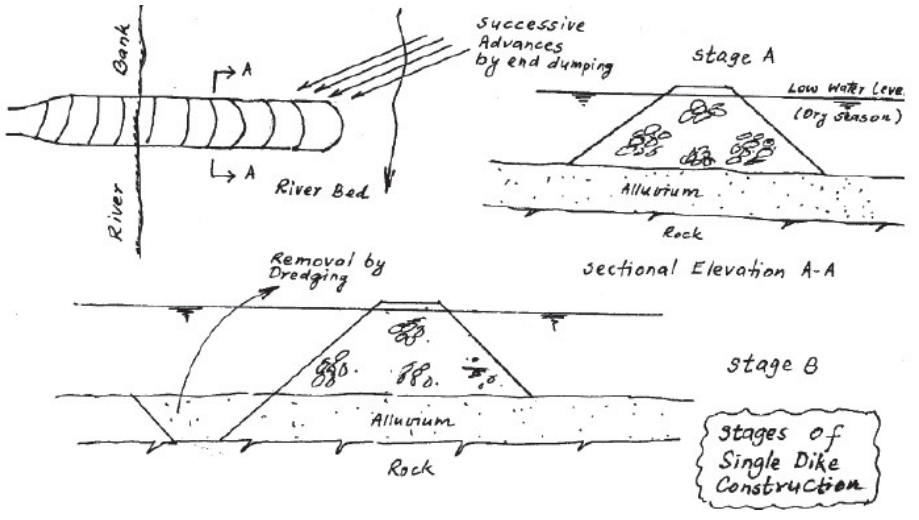
5.1 Cofferdam construction in flowing water

Usual cofferdam solution is the use of embankments (earthfill, rockfill), that is more economical than sheet piles and cells when space is available.

Normal construction procedure: End dumping of rockfill forming 1 or 2 dikes, dredging of loose material from foundation area; dumping of soil material upstream or in core zone.(See Fig 4). Rockfill material, which is stable, should be used. Since these materials are dumped to riverbed without any preparatory work at bed, foundation treatment of such cofferdam sometimes is very difficult.

Alternative construction technique: bottom dumping from barrages or bridge.

Construction of a cofferdam is often a very difficult task. Cases have been reported, when the cofferdams have failed totally or partially. Therefore, for complex cases, hydraulic model testing seems to be very important.



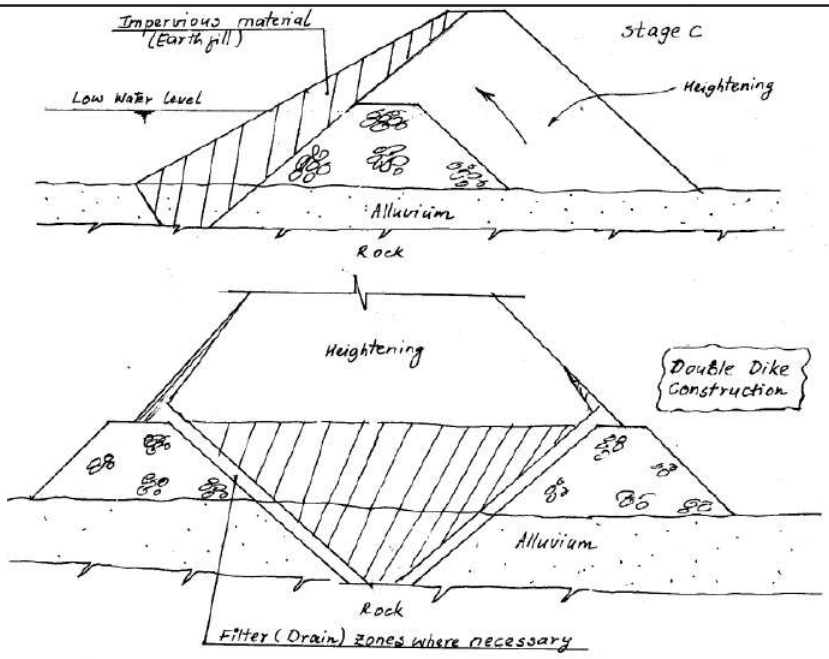
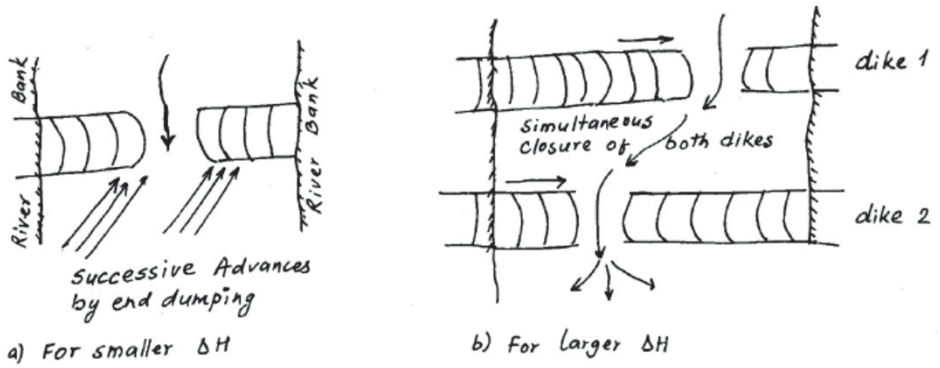


Fig 4: Stages of Single and double dike Construction

5.2 River closure

Final crossing of river channel with a cofferdam is often a difficult task. This portion of cofferdams should be constructed very rapidly under a favorable weather forecast. The closure section must be constructed of weatherproof materials that often must be placed under water. Dumped rock with sufficient fines to form an impervious barrier would be an ideal material. Materials for the closure section must be readily available. To effect a quick closure, it is often expedient to stockpile all the needed materials on the stream bank. The time limits for completion of the closure section of the cofferdam should be based on reasonable production requirements for a 24-hour workday.



Size of blocks depend on net head, Δ H available on closure area (ΔH = difference of water level between upstream and downstream of breach). Roughly, the diameter of blocks, D required be equal to 30% ΔH. The diameter of stone required could be estimated by Isbash Equation for the movement of stone in flowing water as given below:

$$V = C\left[2g\left(\frac{\gamma_s - \gamma_w}{\gamma_w}\right)\right]^{\frac{1}{2}} D^{\frac{1}{2}}$$

where,

V - Velocity, fps

C - Isbash constant, (0.88 for high turbulance level flow and 1.2 for low turbulance level flow

γ_s, γ_w - specific weights of stone and water respectively, lb/ft^3

D - Stone diameter, ft

5.3 Floods overtopping cofferdams and construction site

Sometimes floods overtopping cofferdams and construction site may be an economic solution. Especially, when the valley is wide, repairable damage may be expected in the partially completed structure/dam as the intensity of discharge passing through the structure is insignificant. Care must be taken, however to strengthen the top and the downstream slope of the cofferdam to minimize erosion and damage to the structure. The overtopping flow must be spread over the longest possible length of the cofferdam, thus reducing the concentration of flow.

The overtopping is allowed only during first year/s of construction. The protection of cofferdams can be done by the following measures:

- Anchor bars with wire mesh.
- Grib walls (heavy blocks)
- Gabion mattress
- Anchored concrete plates

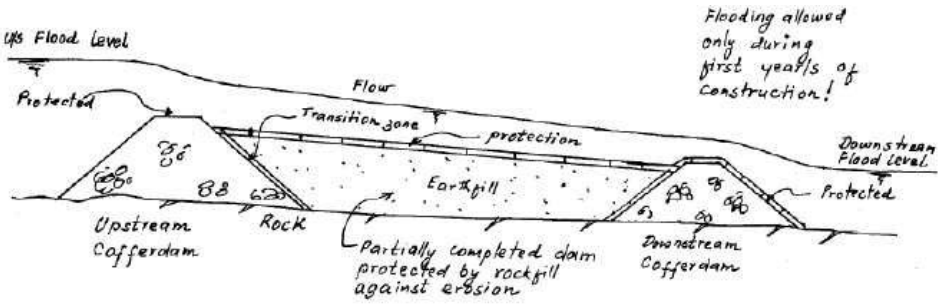


Fig 6: Flood Overtopping Cofferdam and construction site

5.4 Other Requirements

In several projects, choking of bottom outlets, diversion tunnels have been reported which caused severe threats to the cofferdam as well as main structrure/s. Therefore, the control of floating debris is another essential requirement in order to minimize the clogging of diversion tunnels, bottom outlets, control gates, especially during the high-flow season.

6. General methodology for the planning and design of diversion works

a) On the basis of the specific requirements of the dam project identify the possible diversion schemes with their respective phases and sequences.

b) Determine required discharge capacities (for each phase) by a cost - risk analysis or other equivalent criterion.

c) Conceive type and main characteristics of component works of each alternative scheme. Preliminary design; Cost evaluations; and Optimize each alternative.

d) Compare alternatives and select the most interesting (cost, constructive feasibility, schedule, reliability)

e) Detail the selected alternative and it's components

f) Carry out hydraulic model studies for specific purposes (flow conditions, construction conditions, etc.)

Safety of Dams

1.0 Causes of Failure of Dams

The main causes of dam failures are: overflow over the dam; collapse of the spillway, and, foundation collapse or seepage through the foundation. A comparative analysis shows the following factors to be important for failure in earth dams:

- Overflow during flood because of inadequate spillway capacity or non-functioning of the flood gates;
- Internal erosion in the foundation area as a result of unduly high permeability;
- Large settlements in the embankments or foundations;
- Contact erosion in the dam-foundation or a concentrated piping effect in the dam or along the bottom outlet, as long as this is not through the dam;
- Inhomogeneity in the foundation or dam (leading to foundation failure or erosion and suffusion);
- Liquefaction; and
- Cracks following settlements with resulting piping effects.